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Original Article

Development and application of an online testing system for clinical nurses

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ABSTRACT

The online assessment is a new examination system which has a broad application in many research fields such as medical science and has been proved to be effective, reliable, and robust. The aim of this study was to establish an online testing system for clinical nurses and to assess its effectiveness compared with traditional paper-based tests in China. A randomized controlled trial was performed, a total of 1802 nurses were recruited and randomly assigned to take either the paper-formatted test or the online test. Then the paper quality, examinee's performance and nurses' assessments of online testing system were evaluated. The results shown that online assessment system for clinical nurses had a comparable examination effects with traditional paper-based format, and the nurse spoke highly of its effectiveness and efficiency. These data suggest that online nursing assessments should be considered a dependable replacement for paper test.

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1. Introduction

The “digital healthcare” is a new healthcare management philosophy derived from “hospital information construction,” which is based on high levels of integration, process optimization, and energy conservation [1,2]. Implementation of these practices will lead to optimized practices in nursing management. China currently has 2.8 million registered nurses. Traditional paper-based nurse assessment tests have been limited by their ineffectiveness and wastefulness in terms of manpower, material, and financial resources. The online assessment is a new examination system that has been

shown to be effective, reliable, and robust [3–6]. The development and application of online assessment systems for nurses has attracted attention due to its high level of integration, standardization and paperless attribute of the “digital hospital.” However, few studies have addressed potential weaknesses in the new online assessment system, such as imperfect programming, the quality of assessment questions, and inferior Internet platforms. Importantly, no comprehensive evaluation of its effectiveness has been performed in China. Our study attempts to develop a more reliable, science-based, and practical online assessment system for clinical nurses based on the traditional paper-based test formats. We then conducted an evaluation of its effectiveness.

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2. Materials and methods

2.1. Subjects

We recruited 1802 nurses who participated in the final theory examination in 2013. Participants were randomly assigned to either take the online assessment system or the traditional paper-based test. We ensured no significant difference between the two groups in terms of sex, age, educational background, years of working, or professional titles ($P > 0.05$).

2.2. Analysis of system requirements

System requirements were analysed by assessing the system framework, the basic functional modules, and technical points. The online assessment system was built on B/S (Browser/Server) model and operated on an MS platform following the principles of integrity, standardization, scalability, and security. The whole system was data compatible and expandable.

2.3. Construction of question bank

An expert group was put in place to regularly classify, proof-read, and update all questions. The question bank covered a wide range of question on basic nursing, medical nursing, surgical nursing, obstetrics, gynaecological nursing, and paediatric nursing. Questions were formed as type A, type B, type X, multiple choice, true/false, fill-in-the-blank, short answer, essay, and one case study question.

2.4. Generation of tests

Three types of tests were assembled for this study:

1. Paper tests: We collected a random sampling of test questions, but specified question topics, difficulty, and question format. Three versions of paper tests were randomly distributed to the examinees. Each test version had identical content, but questions were in different orders.
2. Online tests: A testing centre was created in a way to prevent cheating. The online test system could track examinees' responses in real-time, track progress, compute current accuracy, and generate scores. The system was also configured with power failure backups, anti-crash technology, and an alert when five minutes were remaining.
3. Mock tests: The online system also provided mock tests for training purposes.

2.5. Management of tests

The testing systems required the following managerial upkeep:

1. Question bank management: Questions were organized categorically in a tree-like structure. The system could customize the question topic, format, and difficulty of

questions. It could also accept bulk importing, error location, and similarity check.

2. Paper test management: The system was designed with the ability to print, reorganize, modify, review, and evaluate all paper tests.
3. Examination management: The system had the capability to set the examination environment, preventing cheating, security assurance, and enter simulation mode.
4. Score management: Qualified professionals assessed subjective questions, while objective scores were automatically marked correct or incorrect. Test scores were calculated by statistical functions. Results were exported and archived into 20 statistical reports for further utilization.
5. User management: The system could set, modify, and store users' information.

2.6. Examination methods

The experimental group was tested via the online assessment system. Prior to testing, a short training was carried out to ensure that participants knew how to take the exam. The control group was tested using paper tests. Questions included the standard examination syllabus from Basic Nursing (Version V). A total of 100 points were possible, with 30 points from single choice questions, 20 points from multiple choice questions, 20 points for true/false questions, and 30 points for a case analysis.

2.7. Test quality evaluations

Paper tests and online tests were evaluated by calculating difficulty coefficients, distinguishing coefficients, reliability, and validity. Difficulty coefficients (P) were expressed as the average score divided by the total score. Higher P -values indicated less difficulty. Ideal intervals were considered to be ~ 0.6 – 0.8 . Distinguishing coefficients (D) were calculated by $(X_H - X_L)/100$ (X_H = the average score of the top 27% of scores; X_L = the average score of the lowest 27% of scores), $D \geq 0.3$ was considered to be a favourable value. Reliability, representing the consistency and stability, was calculated by Cronbach's α . Reliable values were set at 0.4 – 0.76 . Validity, representing the accuracy and effectiveness of the paper test, was calculated by criterion-related validity. Scores were considered reliable between 0.4 and 0.7 [7]. The 2012 test results were also compared to the current results.

2.8. Performance evaluation

The average test scores of the two groups were evaluated to determine their comparability.

2.9. Nurses' assessments of online testing system

To get nurses' opinions on the online testing system, a questionnaire was given to the experimental group. The questionnaire included questions on satisfaction, fairness,

economic effects, management aspects, procedure standardization, information integration, and overall user experience. A total of 28 questions were asked. Each item required the participant to rate the statement from one to five, where a one represented a “very low”/“totally disagree” response and a five represented a “very high”/“totally agree” response. The average was calculated for each item. A pre-test showed that the Cronbach's α of this questionnaire was 0.891 and the Content Validity Index (CVI) was 0.785. A total of 901 questionnaires were sent out to the online test-takers. 854 questionnaires were collected, and the valid response rate was 94.78%.

2.10. Statistical analysis

Epidata 3.1 software was used to input data. Scores were expressed as mean standard deviations from their means. Differences between groups were assessed by student's *t* tests. Enumeration data was presented as proportions and was analysed by chi-square tests. All statistical procedures were performed with SPSS 18.0 software (SPSS Inc., Chicago, IL, USA). *P*-values of <0.05 were considered to be significant.

3. Results

3.1. Paper quality evaluation

The difficulty coefficient, distinguishing coefficient, reliability and validity of traditional paper-based test and online assessment system were 0.74 and 0.73, 0.33 and 0.31, 0.726 and 0.714, 0.703 and 0.691, respectively (Table 1). These values indicate that the online system had a valid and comparable quality with the paper-based test.

3.2. Performance evaluation

No significant differences were detected between the two groups' average scores or pass rates (Table 2). These results further demonstrate the comparability of the two models.

3.3. Nurses' appraisal of online assessment system

The survey results showed that each item received a high score, indicating that clinical nurses spoke highly of the online assessment system (Table 3).

Table 1 – Comparison of paper quality between traditional paper-based test and online assessment.		
Item	Traditional paper-based test (n = 901)	Online assessment system (n = 901)
Difficulty	0.74	0.73
Differentiation	0.33	0.31
Reliability	0.73	0.71
Validity	0.70	0.69

4. Discussion

4.1. Online assessment system is comparable to paper tests

The current study demonstrates that our online nursing competency assessment system is as good as paper tests. We show that both formats are equally difficult, have similar distinguishing coefficients, and are reliable. For validity, the paper test was found to be outside of the acceptable range. We expand upon previous studies that claim online assessments are superior to paper tests. Our approach is superior in that it was performed as a **randomized controlled trial**. Further, a brief training was carried out in our online test group prior to the examination for quality control purposes. Our results are in line with meta-analyses carried out by Wang et al. (2008) [8], and Kingston et al. (2009) [9], which included 12 studies from 1999 to 2007. However, another meta-analysis conducted by Mead et al. (1993) [10] reported the opposite. These results are surprising in light of today's rapid and extensive research and development of digital testing.

4.2. Online assessment systems are more economical and managerially compliant

Questionnaire results showed that clinical nurses thought favourably of the online testing system. In particular, participants responded positively about the economic and managerial aspects of the system. Economically, online testing systems are cheaper in the long-term. For system management, online assessments have greater storage capacities and have greater flexibility in terms of location and timing.

Our hospital is a large modern hospital with extensive teaching, research, and training programs. It employs over 3000 nurses—all of whom must take the final nursing test. In the past, nursing instructors spent 3–4 weeks printing and stapling tests, coordinating the examination site, and finding proctors. This practice was a drain on manpower, materials, and financial resources. Further, it enhanced the risk for cheating. After the test, grading papers, analysing scores, and releasing the results took another 5–8 persons working for about two weeks. Human error was inevitable and impartiality probable.

After the initial launch of the nursing online assessment system, we saw a significant reduction examination costs. Multimedia classrooms accommodate up to 50 examinees and operate on a system where a new examinee begins as soon as the one person is done. Nearly 2000 nurses completed the test within three days. Powerful, robust data analyses by online

Table 2 – Comparison of performance between traditional paper-based test and online assessment system.				
	Traditional paper-based test (n = 901)	Online assessment system (n = 901)	<i>t</i> or χ^2 value	<i>p</i>
Average ($\bar{x} \pm s$)	73.69 \pm 12.96	72.85 \pm 12.08	<i>t</i> = 1.423	0.155
Pass rate (%)	87.12	85.01	χ^2 = 1.671	0.196

Table 3 – Nurses' appraisal of online assessment system.

Dimensions	Numbers of Items	Average score ($\bar{x} \pm s$)	Percentage of total score (%)
Satisfaction	1	4.82 \pm 0.48	96.4
Fairness	3	4.70 \pm 0.56	94.0
Economic effects	7	4.75 \pm 0.52	95.0
Management effects	3	4.69 \pm 0.60	93.8
Procedure standardization	4	4.65 \pm 0.63	93.0
Information integration	4	4.67 \pm 0.59	93.4
User experience	6	4.60 \pm 0.65	92.0
Percentage of total score = average score/5 \times 100%.			

systems provide more efficient and comprehensive results and include zero calculating error.

4.3. Online assessment systems are highly standardized and use information integration

Information integration is the technical term for digital information collection, storage, classification, analysis, and sharing. Such practices allow for system standardization, which is the foundation of modern management practices. The design of the online assessment system substantial emphasis was placed on procedure standardization and information integration. As a result, several separate parts of the system functioned in a coordinated fashion. Questionnaire results showed relatively high scores for both standardization and information integration, suggesting that these aspects were successfully implemented.

4.4. Online assessment systems are optimized for a user-friendly experience

Questionnaire results showed that participants were also pleased with the user interface, the ease of operation, the ability to review and revise answers, the time remaining function, and the flexibility of screen viewing options. Further, participants found the online assessment to be both fair. Nursing education administrators should therefore be committed to further testing optimization and to extend its application in other aspects of nursing education.

5. Conclusion

Our online assessment system had comparable examination effects with traditional paper-based formats. Importantly, it also has favourable evaluations from its users. The system has several advantages over paper tests, including immediate assessment, standardization, and information integration. Such systems are transforming paper-based testing formats. The online assessment system for clinical

nurses has shown outstanding strengths and should be widely implemented.

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Conflicts of interest

The authors declare that there are no conflicts of interest.

Author contributions

CHEN conceived the study, designed the trial, and obtained research funding. CUI and ZHANG supervised the conduct of the trial, data collection and analysis, and quality control. CHEN takes responsibility for the paper as a whole.

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